CLAIMS

What is claimed is:

1. A reforming fuel cell system comprising:

a reformer converting a hydrogen-containing fuel to produce an H_2-containing reformate having a level of carbon monoxide;

a first reactor operable to reduce said level of carbon monoxide of said reformate;

a fuel cell stack generating electrical energy from said reformate and discharging an H_2-containing anode effluent and an O_2-containing cathode effluent;

a combustor having a catalyst bed disposed therein for burning said anode effluent to generate an exhaust gas;

a heat exchanger thermally coupled to said first reactor to control the temperature thereof, said heat exchanger having an input fluidly coupled to said combustor to receive said exhaust gas; and

a controller operable for metering air flow to said combustor to control the combustion temperature thereof;

2. The fuel processor according to Claim 1 wherein said controller comprises:

a cathode control valve system disposed between said fuel cell stack and said combustor, said cathode control valve system operable to direct

said cathode effluent to said combustor to control the temperature of said combustor as a function of the H_2 content of said anode effluent.

3. The fuel processor according to Claim 2 wherein said cathode control valve system comprises:

a first control valve fluidly coupled between said fuel cell stack and said combustor, said first control valve selectively actuated between an opened position to enable flow of said cathode effluent to said combustor and a closed position to prevent flow of said cathode effluent to said combustor; and

a second control valve fluidly coupled between said fuel cell stack and an exhaust passage, said second control valve selectively actuated between an opened position to enable exhausting of said cathode effluent and a closed position to provide a back pressure to facilitate flow of said cathode effluent through said first control valve.

4. The fuel processor according to Claim 1, further comprising:

a second reactor disposed between said first reactor and said fuel cell stack, said second reactor being operable to further reduce carbon monoxide levels of said reformate exiting said first reactor;

a combustion heater outputting a heated exhaust stream; and

a start vaporizer disposed downstream from said combustion heater, said start vaporizer being exposed to said heated exhaust stream for vaporizing an inlet fluid to produce a steam, said steam from said start vaporizer

being directed to a heat exchanger element associated with said second reactor for heating said second reactor.

5. The fuel processor according to Claim 4, further comprising:

a spray vaporizer selectively injecting a cooling fluid into said heated exhaust stream to reduce the fluid temperature thereof.

6. The fuel processor according to Claim 4, further comprising:

a run vaporizer exposed to an exhaust flow from a heat exchanger element of said first reactor for vaporizing an inlet fluid to produce a steam, said steam from said run vaporizer being directed to an inlet of said reformer.

7. The fuel processor according to Claim 1, further comprising:

a second reactor disposed between said first reactor and said fuel cell stack, said second reactor being operable to further reduce carbon monoxide levels of said reformate exiting said first reactor;

a combustion heater outputting a heated exhaust stream;

a spray vaporizer selectively injecting a cooling fluid into said heated exhaust stream to control the fluid temperature thereof; and

a start vaporizer fluidly coupled to said combustion heater, said start vaporizer being exposed to said heated exhaust stream for vaporizing an inlet fluid to produce a steam stream, said steam stream being directed to a heat exchanger element of said second reactor for heating said second reactor;

wherein a flow through said combustion heater, said spray vaporizer, said start vaporizer, said first reactor, and said combustor is reversible so as to alternatively position said combustion heater, said spray vaporizer, and said start vaporizer upstream and downstream from said first reactor.

8. A fuel processor for rapid start and operational control, said fuel processor comprising:

a plurality of fuel cells discharging an H_2-containing anode effluent and an O_2-containing cathode effluent;

a reformer converting a hydrogen-containing fuel selected from the group consisting of alcohol and hydrocarbons to H_2 to produce a reformate for fueling said plurality of fuel cells;

a shift reactor disposed between said plurality of fuel cells and said reformer, said shift reactor having a catalytic region operable to reduce carbon monoxide levels of said reformate and a heat exchange region;

a preferential oxidation reactor disposed between said shift reactor and said plurality of fuel cells, said preferential oxidation reactor being operable to further reduce carbon monoxide levels of said reformate exiting said shift reactor;

a combustor providing hot exhaust gas to said heat exchange region of said shift reactor, said combustor having a catalyst bed disposed therein for burning said anode effluent and said cathode effluent to generate said hot exhaust gas;

a combustion burner operably coupled to said combustor, said combustion burner outputting a heated exhaust stream; and

a cathode control valve system disposed between said plurality of fuel cells and said combustor, said cathode control valve system operable to direct said cathode effluent to said combustor to control a temperature of said combustor when the H_2 content of said anode effluent increases.

9. The fuel processor according to Claim 8 wherein said cathode control valve system comprises:

a first control valve fluidly coupled between said plurality of fuel cells and said combustor, said first control valve selectively actuated between an opened position to enable flow of said cathode effluent to said combustor and a closed position to prevent flow of said cathode effluent to said combustor; and

a second control valve fluidly coupled between said plurality of fuel cells and an exhaust passage, said second control valve selectively actuated between an opened position to enable exhausting of said cathode effluent and a closed position to provide a back pressure to facilitate flow of said cathode effluent through said first control valve.

10. The fuel processor according to Claim 9, further comprising:

a spray vaporizer selectively injecting a cooling fluid into said heated exhaust stream to reduce the fluid temperature thereof; and

a start vaporizer disposed downstream from said combustion burner, said start vaporizer being exposed to said heated exhaust stream for vaporizing an inlet fluid to produce a steam, said steam from said start vaporizer being directed to a heat exchanger element associated with said preferential oxidation reactor for heating said preferential oxidation reactor.

11. The fuel processor according to Claim 10, further comprising:

a run vaporizer exposed to an exhaust flow of said heat exchanger region of said shift reactor for vaporizing an inlet fluid to produce a steam, said steam from said run vaporizer being directed to an inlet of said reformer.

12. The fuel processor according to Claim 8, further comprising:

a spray vaporizer selectively injecting a cooling fluid into said heated exhaust stream to control the fluid temperature thereof; and

a start vaporizer fluidly coupled to said combustion burner, said start vaporizer being exposed to said heated exhaust stream for vaporizing an inlet fluid to produce a steam stream, said steam stream from said start vaporizer being directed to a heat exchanger element of said preferential oxidation reactor for heating said preferential oxidation reactor;

wherein a flow through said combustion burner, said spray vaporizer, said start vaporizer, said shift reactor, and said combustor is reversible so as to alternatively position said combustion burner, said spray vaporizer, and said start vaporizer upstream and downstream from said shift reactor.

13. A fuel processor for rapid start and operational control, said fuel processor comprising:

a plurality of fuel cells discharging an H_2-containing anode effluent and an O_2-containing cathode effluent;

a reformer converting a hydrogen-containing fuel selected from the group consisting of alcohol and hydrocarbons to H_2 to produce a reformate for fueling said plurality of fuel cells;

a shift reactor disposed between said plurality of fuel cells and said reformer, said shift reactor being operable to reduce carbon monoxide levels of said reformate;

a preferential oxidation reactor disposed between said shift reactor and said plurality of fuel cells, said preferential oxidation reactor being operable to further reduce carbon monoxide levels of said reformate exiting said shift reactor;

a combustor providing hot exhaust gas to said shift reactor, said combustor being fueled by said fuel and said anode effluent, said combustor having a catalyst bed disposed therein for burning said fuel and said anode effluent to generate said hot exhaust gas;

a combustion burner operably coupled to said combustor, said combustion burner outputting a heated exhaust stream;

a spray vaporizer selectively injecting a cooling fluid into said heated exhaust stream to reduce the fluid temperature thereof; and

a controller operable for metering air flow to said combustor to control the combustion temperature of said combustor.

14. The fuel processor according to Claim 13, further comprising:

a cathode control valve system disposed between said plurality of fuel cells and said combustor, said cathode control valve system operable to direct said cathode effluent to said combustor to limit a temperature of said combustor when the H_2 content of said anode effluent increases.

15. The fuel processor according to Claim 14 wherein said cathode control valve system comprises:

a first control valve fluidly coupled between said plurality of fuel cells and said combustor, said first control valve selectively actuated between an opened position to enable flow of said cathode effluent to said combustor and a closed position to prevent flow of said cathode effluent to said combustor; and

a second control valve fluidly coupled between said plurality of fuel cells and an exhaust passage, said second control valve selectively actuated between an opened position to enable exhausting of said cathode effluent and a closed position to provide a back pressure to facilitate flow of said cathode effluent through said first control valve.

16. The fuel processor according to Claim 13, further comprising:

a start vaporizer disposed downstream from said combustion burner, said start vaporizer being exposed to said heated exhaust stream for vaporizing an inlet fluid to produce a steam, said steam from said start vaporizer being directed to a heat exchanger element associated with said preferential oxidation reactor for heating said preferential oxidation reactor.

17. The fuel processor according to Claim 16, further comprising:

a run vaporizer exposed to an exhaust flow from a heat exchanger element of said shift reactor for vaporizing an inlet fluid to produce a steam, said steam from said run vaporizer being directed to an inlet of said reformer.

18. The fuel processor according to Claim 13, further comprising:

a start vaporizer fluidly coupled to said combustion burner, said start vaporizer being exposed to said heated exhaust stream for vaporizing an inlet fluid to produce a steam stream, said steam stream from said start vaporizer being directed to a heat exchanger element of said preferential oxidation reactor for heating said preferential oxidation reactor;

wherein a flow through said combustion burner, said spray vaporizer, said start vaporizer, said shift reactor, and said combustor is reversible so as to alternatively position said combustion burner, said spray vaporizer, and said start vaporizer upstream and downstream from said shift reactor.

19. A method for controlling a reforming fuel cell system, the method comprising the steps of:

generating a H_2-containing reformate in a reformer, said reformate having a level of carbon monoxide;

passing said reformate through a first reactor to reduce said level of carbon monoxide in said reformate;

reacting said reformate with oxygen in a fuel cell stack to create electrical energy and an anode effluent;

inputting said anode effluent into a combustor to generate a exhaust stream;

adjustably inputting an oxidant into said combustor to control the temperature of said exhaust stream; and

transferring heat from said exhaust stream to said first reactor such that the temperature of said first reactor is maintained within an operating range.

20. The method of claim 19 wherein the heat generated in said first reactor is balanced with the heat transferred to said first reactor from said exhaust stream to maintain said the temperature of said first reactor within said operating range.

21. The method of claim 19 wherein the step of adjustably inputting an oxidant into said combustor is based on the temperature of said first reactor.

22. The method of claim 19 wherein said fuel cell stack creates a cathode effluent which is adjustably input into said combustor as said oxidant.

23. The method of claim 19 further comprising the step of controlling the temperature of said exhaust stream by extracting heat from said exhaust stream prior to transferring said heat to said first reactor.

24. The method of claim 23 wherein the step of extracting heat from said exhaust stream comprises introducing a cooling spray stream into said exhaust stream.

25. The method of claim 24 further comprising the step of adjusting the rate of said cooling spray stream as a function of the amount of said anode effluent produced.

26. The method of claim 23 wherein the step of extracting heat from said exhaust stream comprises passing said exhaust stream through a vaporizor to produce a steam stream.

27. The method of claim 26 further comprising the step of inputting said steam stream through a second reactor disposed between said first reactor and said fuel cell stack.

28. The method of claim 27 further comprising the step of adjusting a rate of steam stream through said second reactor such that the temperature of said second reactor is maintained within a second operating range.

29. In a fuel processing system of the type having a reformer breaking down a hydrocarbon fuel into an H_2 containing reformate stream and first and second rectors disposed downstream of the reformer for reducing the level of carbon monoxide in the reformate stream, a method of rapidly starting the fuel processing system:

generating a heated gas stream in a heating device;

directing said heated gas stream through a first side of a heat exchanger;

directing water through a second side of said heat exchanger to produce a steam stream;

heating said first reactor with said heated gas stream at a first rate of heating;

heating said second reactor with said steam stream at a second rate of heating; and

controlling said heating device to adjust said heated gas stream, thereby controlling said first and second rates of heating.

30. The method of rapidly starting a fuel processing system of Claim 29, further comprising the step of injecting water into said heated gas stream to control the temperature of said heated gas stream.

31 The method of rapidly starting a fuel processing system of Claim 29, further comprising adjusting said heating device as a function of the temperature of at least one of said first and second reactors.

32 The method of rapidly starting a fuel processing system of Claim 29, further comprising the step of generating a second heated gas stream in a second heating device and directing said second heated gas stream through said reformer to heat said first reactor at a third rate of heating.

33. The method of rapidly starting a fuel processing system of Claim 32, further comprising the step of heating said reformer with said steam stream.

34. The method of rapidly starting a fuel processing system of Claim 33, further comprising the steps of directing said reformate stream through a first side of a second heat exchanger and directing said steam stream through a second side of said second heat exchanger.